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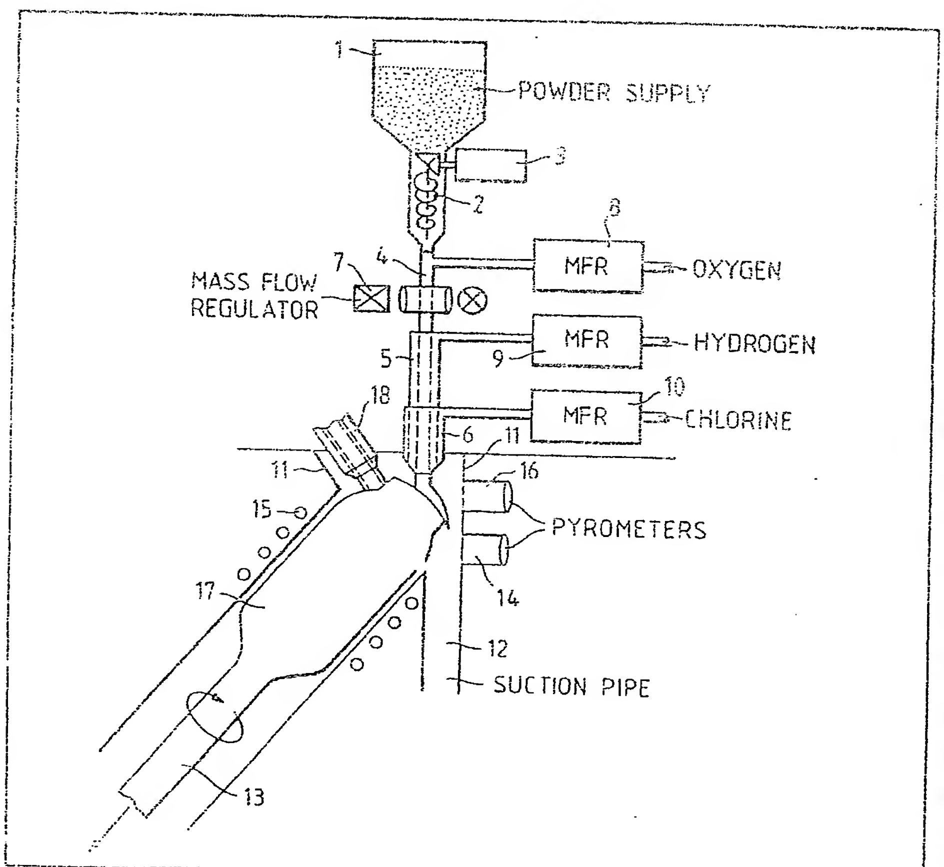
(54) **Optical waveguide preform fabrication**

(57) Powdered silica optionally mixed with dopant (e.g. GeO_2) is introduced via dosing feeder 2 coaxially into a ring- or tube-shaped heating device such as oxyhydrogen burner 4, 5, 6, where the powder melts/evaporates and may be treated with a gas (e.g. chlorine) to remove hydroxyl groups and impurities. The glass is deposited from the liquid/vapour phase onto the end of rotating substrate 13 to produce preform 17 which may be coated in a second deposition process using burner 18.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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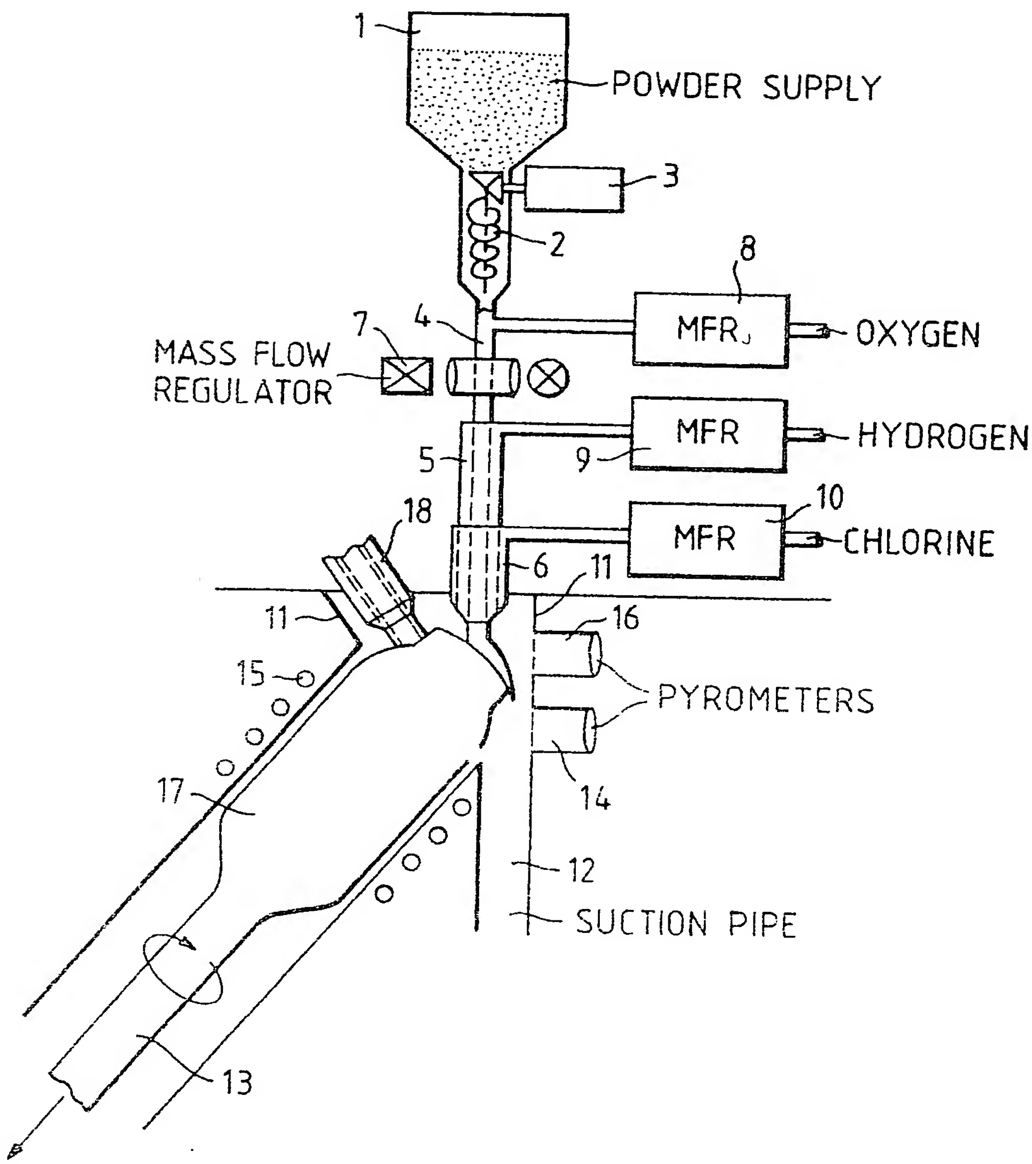
1
POWDER SUPPLY
3
2
8
MFR
OXYGEN
4
7
MASS FLOW
REGULATOR
MFR
HYDROGEN
5
9
10
18
MFR
CHLORINE
6
11
11
16
15
PYROMETERS
17
14
12
SUCTION PIPE
13

SPECIFICATION

An optical waveguide fabrication process

This invention relates to an optical waveguide fabrication process in which there is first fabricated a preform from which the optical waveguide is drawn and more particularly to such a process in which the preform is formed from particle-shaped glass material deposited onto a rotating substrate.

Such processes in which the glass material of the preform to be produced, is deposited in particle shape onto a rotating substrate are known, for example, from DE—AS 23 13 203 and 27 15 333.

Common to all conventional processes of this kind is the feature that the particle-shaped glass material to be deposited, is produced in one or more burners by way of a chemical oxidation reaction, and is deposited onto the rotating substrate directly following the reaction, in the course of which, for example, $SiCl_4$ and $GeCl_4$ are oxidised in the flame into SiO_2 and GeO_2 respectively. Accordingly, as a rule chlorides or oxychlorides are used as the starting materials in these processes. Owing to their reactive characters, these compounds must be stored in absolutely water-free surroundings. Usually, quartz-glass containers are used as storing and transporting vessels. These vessels, however, must be handled with great care.

DE—OS 30 00 762 discloses a process for depositing a cladding layer onto a rod of core-glass material, without the manufacture thereof being disclosed. In this process, as the starting materials, oxides are used instead of the chlorides and the deposition of the particle-shaped material is not linked to an oxidation reaction. Here, the glass powder as supplied by gravity transversely in relation to the flame of a plasma burner, is taken along by the flame and deposited on the flame-heated surface of a rotating rod of core-glass material in such a way that a homogeneous vitrified layer results. Since the particles of the glass powder are fused into small drops in the flame and are deposited onto the substrate by being simultaneously vitrified, this process hardly prevents the deposited glass from being adequately purified, and the avoidance or subsequent removal of hydroxyl-group inclusions is hardly possible in this process.

For the growing of monocrystals it is known from DE—PS 24 15 110 to use the so-called Verneuil process in which powdered oxidic material is coaxially introduced into a tubular oxyhydrogen burner where it is fused and deposited onto a coaxially arranged plate which rotates during the deposition and is moved in the axial direction away from the oxyhydrogen burner in accordance with the growing speed of the deposited material.

In that process the dosing of the powder supply is not controlled, and the use of silicon dioxide as the powdered oxidic starting or raw material is not suggested.

The present invention seeks to provide a process for fabricating optical waveguides which avoids the use of chlorides and oxychlorides which are difficult to handle and, at the same time, permits fabrication of preforms of high purity.

According to the invention silicon dioxide powder is introduced at a controlled rate into a heat-producing device in which it is liquefied or evaporated in a gas stream and is thereby deposited onto the rotating substrate.

Preferably the powder is introduced, at said controlled rate, via a dosing feeder coaxially into the heat producing device which is of annular or tubular form.

The silicon dioxide powder may contain a dopant powder.

In order that the invention and its various other preferred features may be understood more easily, an example thereof will now be described, by way of example only with reference to the drawing which shows an apparatus for producing a preform in accordance with the process of the invention.

The raw material for the process to be described hereinafter, is a powder of silicon dioxide or else a powder mixture of silicon dioxide and oxidic dopant, such as germanium dioxide. Such powdered raw material, can be handled and stored in large quantities without requiring any expensive safety arrangements.

The powder is contained in a supply vessel 1 from which it is introduced via a dosing feeder, in the form of a worm conveyor 2 having a controlled worm gear drive 3, into a heat-producing device which either liquefies or evaporates the powder and, thereafter, deposits it in the form of a particle-shaped glass material on a substrate. In the embodiment described, the heat-producing device is an oxyhydrogen burner consisting of several coaxial tubes, in the present case three coaxial tubes 4, 5 and 6. The powder material is introduced into the inner tube 4 of the burner by the worm conveyor 2. The tube 4 also serves as an oxygen-supply tube. By supplying oxygen, there is produced a homogeneous gas-powder mixture. The worm conveyor 2 determines the quantity of powder to be introduced into the burner per time unit. For controlling the amount of powder to be introduced per time unit (dosing), there is provided a mass-flow regulator 7. Depending on the required measuring accuracy, mass-flow measurements can be carried out in accordance with various principles, for example, it is possible to carry out optical transmission measurements, optical stray measurements or else a capacitive measurement of the mass flow, the latter in particular because the dielectric constant of the powder distinctly differs from value 1.

Hydrogen is introduced into the middle one of the burner tubes 5, and via the outer tube 6 a gas can be introduced into the burner flame, in order thus to clean the powder as vaporised in the flame and to avoid hydroxyl groups in the deposited material. As a rule, it is suitable to this end to use gases which, together with impurities in the form

of transition metals and with hydroxyl groups, form compounds which are volatile at the deposition temperature. For example, chlorine gas is suitable for this purpose. If necessary, also a protective gas, such as argon, may be added to the chlorine gas. For regulating the velocities of flow of hydrogen, oxygen and chlorine, there is provided mass-flow regulators 8, 9 and 10 respectively.

The burner as described extends into a combustion chamber 11 which has a gas-tight entrance on its top side, and comprises a suction tube 12 permitting exhaust gases and water vapour to be sucked off. In the combustion chamber, the powder material is introduced into the burner into the flame burning therein. The powder is vaporised or liquefied, so that a purification and a removal of hydroxyl groups can be carried out from the vapour or liquid phase. Possibly following a recondensation, particle-shaped glass material is deposited from the vapour or liquid phase on a substrate.

From a process-engineering point of view it may be more favourable, under certain circumstances, to carry out the purifying of the material and the removal of hydroxyl groups with the aid of the chlorine gas separate from the flame. In this case a cleaning gas e.g. chlorine is not added to the powder/gas mixture in the vicinity of the flame but the deposited particle-shaped material is subjected to a treatment with for example chlorine in the course of a later processing step. In that case, the burner would serve just to deposit particle-shaped glass material on a substrate.

The substrate on which the recondensed material as emerging from the flame, is deposited, is positioned inside the combustion chamber 11 in such an orientation that the spacing between the burner head and the location of deposition on the substrate can be regulated. In the example described, for depositing material on the substrate, there is used a process in which a preform grows in the axial direction with respect to the substrate axis. As the substrate, there is used a glass rod 13 rotating about its longitudinal axis, and the deposition is effected onto the end of the preform growing thereon.

The temperature inside the combustion chamber, and in particular the temperature of the deposition surface, is determined with the aid of a pyrometer 14, and is controlled with the aid of an additional heater 15, such as a resistance heating element surrounding the growing preform, or else via the fuel-gas supply. The flame temperature is determined with the aid of a second pyrometer 16.

The deposition conditions existing inside the combustion chamber, with the pressure capable of being regulated via the suction tube, can now be adjusted in such a way that the preform 17 produced has a porous or a vitreous composition. A porous preform which later on has to be fused to a vitreous preform, is preferred in cases where the aforementioned purification from the vapour phase is inadequate and still requires a subsequent treatment for the purpose of purification or for removing hydroxyl groups.

In order to be able to deposit a second material with a different composition onto the first material which has resulted from the axial growth of the material deposited by the burner previously described, there is provided a second burner 18. The second burner 18, only the burner head of which is shown, extends into the combustion chamber, is designed similarly to the first burner, and is supplied and controlled in a similar manner. This second burner 18 deposits in a direction substantially normal to the axis of rotation of the substrate, and thus permits the outer surface of the material as deposited by the first burner to be coated. The thus deposited material may, for example, be a material having a lower refractive index, which is required as a cladding material for a fibre to be drawn from the preform. The direction in which the substrate is disposed with respect to the axis of the first, shown burner is chosen thus that, with a view to the temperature and the deposition conditions, both burners are in a suitable orientation in relation to the deposition surfaces.

If the core composition is to have a radial gradient of refractive index, then instead of the dirst described burner, there is used in a conventional way a multitube burner which, owing to the arrangement of its burner nozzles or owing to the local temperature distribution, and owing to the supply thereof with powders of different composition, produces the desired refractive index profile.

A possible alternative is to use a burner which, by the suitable arrangement of its nozzles alone, produces the desired refractive index profile from a homogeneous powder mixture.

A further possibility is to use several independent burners arranged in a suitable way.

It is to be noted that several layers can be deposited successively on the outer surface of a rotating substrate by the method previously described.

As the heat-producing device for fusing the powdered raw material, it is possible to use, instead of a gas burner of the type described hereinbefore, also a plasma burner with either an inductive or capacitive plasma coupling, or else also an electric arc burner. It also seems possible to provide the necessary energy in the form of laser pulses.

The powdered raw material, e.g. silicon dioxide powder and, for example, germanium dioxide powder is commercially available from several manufacturers in different quality grades. A grain size of several hundredths of a micron is suitable.

CLAIMS

1. Optical waveguide fabrication process in which there is first fabricated a preform from which the optical waveguide is drawn, and in which for the preform fabrication, particle-shaped

glass material is deposited onto a rotating substrate, characterised in that silicon dioxide powder, is introduced at a controlled rate into a heat-producing device in which it is liquified or evaporated in a gas stream and is thereby deposited onto the rotating substrate.

2. A process as claimed in claim 1, characterised in that the powder is introduced, at said controlled rate, via a dosing feeder coaxially into the heat producing device which is of annular or tubular form.

3. A process as claimed in claim 1 or 2, characterised in that the silicon dioxide powder contains a dopant powder.

4. A process as claimed in any one of the preceding claims, characterised in that a core and a cladding layer of the preform are deposited onto the substrate.

5. A process as claimed in claim 4, wherein the core and cladding layers are deposited simultaneously onto the substrate.

6. A process as claimed in claim 4, wherein the core and cladding layers are deposited one after the other onto the substrate.

7. A process as claimed in any one of the preceding claims, characterised in that said particle-shaped glass material is deposited in such a way onto the rotating substrate that a porous body results, and that the porous body is thereafter fused into a vitreous preform.

8. A process as claimed in any one of claims 1 to 6, characterised in that the particle-shaped glass material is deposited onto the rotating substrate by subjection to an immediate vitrification.

9. A process as claimed in any one of the preceding claims, characterised in that at least one gas is introduced into the heat-producing device, which, with transition metals and with hydroxyl groups, forms compounds which are volatile at the deposition temperature.

10. A process as claimed in any one of the preceding claims, characterised in that additionally an inert gas is introduced into said heat-producing device.

11. A device as claimed in any one of the preceding claims, characterised in that the heat-producing device is a gas burner.

12. A process as claimed in any one of claims 1 to 10, characterised in that the heat-producing device is a plasma burner.

13. A process as claimed in any one of claims 1 to 10, characterised in that the heat-producing device is an electric arcing device.

14. A process as claimed in any one of claims 1 to 10, characterised in that the heat-producing device comprises a laser-pulse generator.

15. A optical waveguide fabrication process substantially as described herein with reference to the drawing.

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